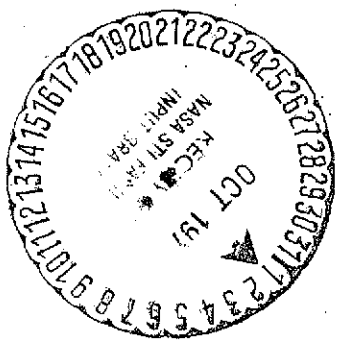
ON THE PROBLEM OF SELF-PURIFICATION OF AIR IN SEALED COMPARTMENTS WITH LIMITED VENTILATION

E. M. Rogozina and A. M. Kozik

Translation of: "K voprosu o samoochishchenii vozdukha v zakrytykh pomeshcheniyakh s ogranichennoy ventilyatsiey," Gigiyena i sanitariya, No. 5, May, 1974, pp. 43 - 45.



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16. Abstract

The action of human metabolites, such as carbon monoxide, carbon dioxide, ammonia, phenol, and hydrogen sulfide, in the atmosphere of a hermetically sealed room (200 m^3) was studied. The surfaces of the room (air cooled) are 4 — 5° cooler than the air, and thus condensation forms at the rate of 160 to 250 g/hour/m^2. At various intervals during the 72 hour experiment, condensation from the room surfaces was analyzed; the results are shown in three charts. It appears that the substances which are water soluble, i.e., acetone, phenol, ammonia, and hydrogen sulfide, are removed from the air in the condensate, while carbon monoxide and carbon dioxide remain in the atmosphere. The amount of water in the air released by human subjects at rest or during light work is sufficient to dissolve significant quantities of water soluble metabolites and thus, to a certain extent, purifies the air.

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ON THE PROBLEM OF SELF-PURIFICATION OF AIR IN SEALED COMPARTMENTS WITH LIMITED VENTILATION

E. M. Rogozina and A. M. Kozik

The problem of self-purification of the air in sealed compartments occupied by humans is very important for solving many practical problems. Based on data of V. I. Kustov and L. A. Tiunov, metabolic discharges contain more than 400 chemical compounds, whose toxicological importance differ. Such human metabolites as carbon dioxide and carbon monoxide, ammonia, phenol, hydrogen sulfide, and others are of great importance for the formation of a gaseous medium in inhabited sealed compartments. We have made a study of the behavior of carbon dioxide and carbon monoxide, acetone, ammonia, phenol, and hydrogen sulfide in the air medium of a hermetically sealed compartment when the condensate separates out on the enclosure surfaces. /43*

The degree to which the air is self-purified of the microcomponents depends on the humidity condensation rate from the air in the compartment upon the surfaces enclosing it. In our studies, the conditions necessary to separate out the condensate upon the enclosures were initiated at the beginning of two days of tests and were maintained up to the end of the experiment, for a total duration of 72 hours. Table 1 gives certain parameters of the microclimate of the experimental compartments.

*Numbers in the margin indicate the pagination of the original foreign text.

TABLE 1

CERTAIN MICROCLIMATE PARAMETERS

Days	Hours	Air Temperature (in degrees)	Relative Air Humidity (in %)	Enclosure Surface Temperature (in degrees)	Dew Point (in degrees)
16	13	31.7	85	25.5 - 27	28.7
16	14	29.9	85	25 - 26.5	27.2
17	8	30.6	80	25 - 27	26.8
17	17	31.7	88	26.5 - 28	29.7

According to Table 1, 1.5 — 2 g of condensate per each kilogram of air, which is in contact with the enclosures, can be separated out from the air passing over the enclosure surface. The condensation rate may be roughly determined from the heat transfer coefficient, whose calculated value in our case is 25 — 30%. Consequently, 160 — 250 g of moisture per hour could be separated out on each square meter of enclosure in the observed drop in the temperature of the air and the enclosure by 4 — 5°. On the whole, this is more than 30 kilograms of moisture per hour in the experimental compartment. The amount of water released by humans into the air under the test conditions (moderate work and rest), varies from 1.09 to 1.7 g/min according to the data of N. K. Vitte. Thus, the test subjects released 4 — 6 kg of water per hour.

Comparing the moisture liberation rate in the compartment with the condensing capacity of the enclosures, it may be concluded that under the conditions of fairly high temperatures of the enclosures the condensing capacity somewhat exceeds the human moisture liberation. With respect to the moisture separation in the air coolers, the condensation of moisture takes place very vigorously in the coolers due to the higher air

velocities and the greater temperature drops of the air and the cooling surfaces. In our case, the temperature of the water pumped through the air cooler ranged between 10 — 14°.

The moisture balance in the experimental compartment (volume of 200 m^3) was 250 kg during 72 hours of tests. Of this amount, 50 kg was removed due to air exchange, operation of the filters, and an increase in air humidity. Consequently, about /44
200 kg of water was separated out during the tests in the form of a condensate on the enclosures and the air coolers.

The human vital products which we studied may be divided into two groups: those readily soluble (phenol, aceton, ammonia) and those which are poorly soluble (CO_2, CO, and H_2S).

The condensate analysis data are given in Table 2.

The results of determining the human metabolites in the compartment air are given in Table 3.

The data in Tables 2 and 3 make it possible to calculate the distribution of human gaseous products in the air and the condensate, with allowance for their reduced contents due to air exchange.

As may be seen from Table 4, the total balance of the metabolite content at all of the possible points was close to 100%. Table 4 gives data on the time: 52 hours from the beginning of the tests. The change in the air composition in inhabited hermetically sealed compartments obeys the well-known laws. Therefore, it may be predicted at any moment. In a compartment with a certain amount of humans, performing the same activities, the O_2 concentration can be established by the

TABLE 2

METABOLITE CONTENT IN CONDENSATE PER 1 ml AND THE ENTIRE VOLUME

Time Interval (hours)	CO_2	CO	Acetone	Phenol	Ammonia	H_2S
	in mg per 1 liter					
24	0.5	not found	0.01	0,001	0,001	0.05
62	1.2	same	0.01	0,004	0,008	0.3
	in grams in entire volume					
24	100	not found	2.0	0.2	0.2	10
62	240	same	2.0	8.0	1.6	60

TABLE 3

CONTENT OF HUMAN VITAL PRODUCTS IN THE AIR OF A SEALED COMPARTMENT, IN ENTIRE VOLUME

Time Interval (hours)	CO_2 (in kg)	CO	Acetone	Phenol	Ammonia	H_2S
		(in grams)				
24	12	4	0.4	3.6	0.4	0.2
52	12	6	0.4	4.0	0.5	0.14

following formula, under the assumption that the consumption of oxygen and the liberation of CO_2 and other metabolites at any moment are the same:

$$q = 21 - \frac{a \cdot t}{R} 100,$$

and the CO_2 concentration can be determined from the formula

$$q_1 = \frac{bt}{R} 100,$$

where q and q_1 are the O_2 and CO_2 concentrations; a — consumption of O_2 (in m^3/hour); b — liberation of CO_2 (in m^3/hour); R — compartment volume (in m^3/hour); t — time (in hours); and 21 — normal content in air (in %).

TABLE 4

DISTRIBUTION OF HUMAN GASEOUS PRODUCTS IN A SEALED COMPARTMENT WITH LIMITED VENTILATION (in %)

Distribution Component	CO_2	CO	Acetone	Phenol	Ammonia	H_2S	Water
air exchange	17	17	17	17	17	17	17
absorption in filters	3	0.3	0	0.3	0.3	0	0.5
in the air	78	83.2	14.2	25.5	20.5	1	0.8
condensate	1.3	not found	68.3	57	62.0	81.5	82.0
Total	99.3	100.5	99.5	99.8	99.3	99.5	100.3

However, these formulas are valid if there are no secondary processes in the compartment being studied. These processes include the interaction between water which is liberated and gaseous components — human metabolites. Based on the Handbook of Chemistry (Volume II), edited by B. Nikol'skiy (Moscow, Goskhimizdat, 1963, p. 14, 261, 461, and 1042), the solubility in water is at a minimum for acetone.

A direct dependence was observed for the content of the components — the metabolites — in the condensate on their solubility in water. Hydrogen sulfide is not included in this almost linear dependence. Its content in the condensate approximates the concentration of acetone, although their solubility values are different. This may be explained by the fact that, during the determination of hydrogen sulfide, a group analysis /45
was made of the SH-containing compounds. This group includes thio alcohols, thio esters, and other compounds, whose solubility is much greater than the solubility of hydrogen sulfide.

Consequently, the soluble compounds enter the condensate from the air when it is separated out on the cooling surfaces, depending on their capacity to be dissolved, which produces self-purification of the air. This fact is confirmed by Table 4. In the condensate, a large amount of metabolites was detected, with the exception of carbon dioxide and carbon monoxide, which are basically found in the air and rarely found in the condensate, whereas acetone, phenol, ammonia, and hydrogen sulfide are dissolved in it during the separation of the condensate and contribute to air purification.

Thus, the water liberated by the humans is adequate to dissolve large amounts of certain human vital products, which would produce a toxic effect if accumulated in the air. The metabolites which, based on computation of data, may reach the maximum permissible concentration in a sealed compartment occupied by humans have high solubility in water, a limited influence upon the composition of the human gaseous medium, and they reduce the toxic effect by dissolving in the condensate which is separated out. In addition, the equilibrium between the content of gaseous compounds in the air and the condensate which is separated out may be shifted toward the liquid phase by a change in the temperature regime.

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